

Numerical Simulations of Ohmic Breakdown Phenomena in a Tokamak

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The ohmic breakdown is a fundamental method to initiate the plasma in a tokamak. Poloidal magnetic field-null and sufficient toroidal electric fields are necessary conditions for robust ohmic breakdown. In the case of superconducting fusion devices such as ITER and beyond ITER, however, low toroidal electric field (< 0.3 V/m) is imposed by terminal voltage limitations on the multi-turn superconducting poloidal field coil system [1]. To design robust and optimal breakdown scenarios, deep understanding and precise analysis of ohmic breakdown phenomena are essential.

For this purpose, two numerical codes, “Field-line-following analysis” and “Drift-kinetic PIC-MCC (Particle In Cell – MonteCarlo Collision)”, are developed to estimate the ohmic breakdown scenarios precisely. Based on Townsend avalanche theory, the field-line-following analysis code measures the exact field-line-integrated physical quantities of the complex magnetic field configuration including stray fields produced by eddy currents. Due to rapid time-varying electromagnetic fields and space charge produced in a device, however, the simple Townsend avalanche theory contains limitations on catching actual phenomena of electron avalanche during breakdown phase.

A drift-kinetic PIC-MCC code is developed to simulate actual avalanche phenomena in a tokamak geometry with rapid time-varying electromagnetic fields. Dominant collisions between charged particles and background neutral gas are treated as MCC scheme. Self-induced electric fields by space charge due to significant difference of mobility between electrons and ions are calculated from Poisson’s equation. Actual time-varying evolutions of electrons and ions can be simulated using this code for the breakdown phase.

These two codes are applied to the ohmic breakdown scenarios of tokamaks such as KSTAR and VEST device and compared with experiments.

[1] ITER Physics Expert Groups, *et al.*, ITER Physics Basis, Nuclear Fusion **39** (1999) 2577